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STUDY OF CYCLE TIME REDUCTION AND ASSEMBLY PROCESS IMPROVEMENT FOR VARIOUS ELECTRIC STACKERS

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Original Article

ABSTRACT

Material handling is a system or combination of methods, facilities, labour, and equipment for moving, packaging and storing of materials to meet specific objectives. A stacker is a machine used in material handling unit. In the present study among the different stackers which are manufactured in maini material movement private limited, electric stackers are considered. These electric stackers can move in horizontal and vertical directions. The vertical movement is controlled by hydraulic actuators and the travelling or horizontal movement is carried out with the help of motor drives. The main objective of this study is assembly process improvement by various methods and cycle time reduction for assembly and welding process.

In order to achieve the objective, assembly and welding process flow chart, time line study for present manufacturing process are to be noted and critical path method is applied to find out critical path and cycle time. By studying the assembly process sheet, various sub-assemblies are suggested to directly import from outside so that the cycle time will be reduced. Then hydraulic steel pipe fitting dimension are noted in order to change pipe end fitting from bsp to standard jic. Then studying the fixtures and tooling, quality management and testing for revised manufacturing process. Finally, standardization of stackers is carried out. That is standardization of 1.5 kw ac vertical drive motor along all stackers and standardization of lifting height of stackers. The key area of concern is that equipments are being manufactured using old methods and needs to be enhanced to the current industry standards with various changes suggested to reduce cycle time. Creo 3.1 software is used for modeling and drafting purpose.

KEYWORDS: Cycle Time, Critical Path Method & Electric Stackers

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INTRODUCTION

Material handling is a system or combination of methods, facilities, labor, and equipment for healthy materials movement during processing to end use. The “Material” in materials handling can be any substance from which a product is assembled or packaged for further processing or sale. Or, it is any item that is assembled, packaged, and distributed for further use. A stacker is a machine used in bulk material handling. Stackers are nominally rated for capacity in tonnes per hour (tph). It can be of hand trucks or powered industrial trucks type. In powered Industrial trucks, there are Low-lift pallet trucks and High-lift pallet trucks. High lift pallet trucks or High reach stackers are capable of self-loading. They are equipped with an elevating mechanism designed to permit tiering. Different types of stackers or trucks coming under this type are counter balanced truck, straddle trucks, fork over arm truck etc. In the present study, among the different Stackers which are manufactured in Maini Material Movement Private

Limited, electric Stackers are considered. These electric stackers can move in horizontal and vertical direction. The vertical movement is controlled by hydraulic actuators and the travelling or horizontal movement is carried out with the help of motor drives. The main objective of this study is to have a well-defined Manufacturing Engineering Process that covers an 'End to End' understanding across all functional areas for Electric Stackers. Figure 1 shows the pictures of electric stackers under study.

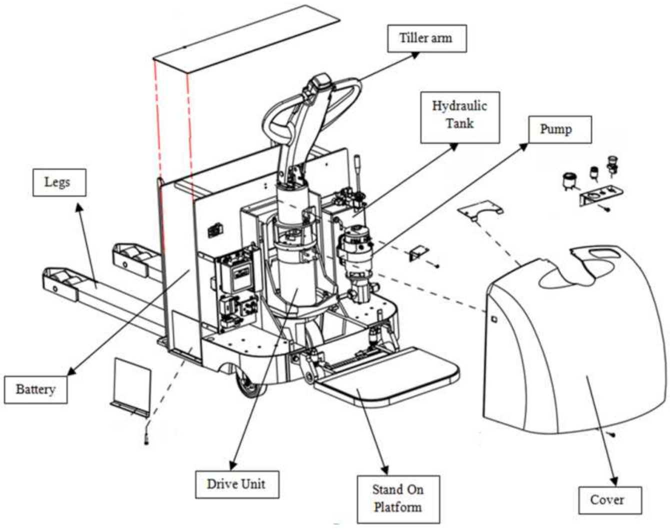

Figure 1: Parts of a Electrical Stackers

OBJECTIVE OF THE WORK

Assembly process flow chart with pictorial representation and time line study for Stacker manufacturing process by studying the Assembly process sheet, various sub-assemblies has to be suggested to directly import from outside so that the cycle time will be reduced. To create multilevel assembly drawing, pipe assembly, tank assembly which will help in reduction of cycle time. Standardization of Stackers : Standardization of Vertical AC Drive Unit across all Stackers, Standardization of Stacker Mast Height, Design and manufacturing of fixtures for Stacker, Structuring of Bill of Materials for required manufacturing process.

Cycle Time Reduction and Assembly Process Improvement

The period required to complete one cycle of an operation; or to complete a function, job, or task from start to finish. Cycle time is used in differentiating total duration of a process from its run time.Cycle time reduction is the strategy of lowering the time it takes to perform a process in order to improve productivity. In addition, cycle time reduction often improves quality. When a cycle time is too close to the takt time, there is little margin for error. If a process is dialed in with very little variation, this is seldom a problem. But most processes have some inconsistency in them, resulting in people falling behind the normal pace on occasion. This leads to them rushing, which, in turn can lead to mistakes. Reducing cycle time is a low cost way to add a bit of a buffer to avoid those sorts of defects. Standard Work provides the framework to do cycle time reduction. There are many studies carried in detail in the field of assembly process improvement and cycle time reduction.

Lee et al [1] in their paper discusses new perspectives for maintenance innovation and proposes the value creation paths for maintenance transformation. With the advent of Internet of Things (IoT), Cloud computing, Big data, PHM, and cyber-physical systems, e-maintenance necessitates new transformation. Kumar et al [2] mentions the application of lean

manufacturing and line balancing in reduction of cycle time in the automobile industries. Rahman et al [3] states that in order to achieve production goals, and with the increase in the requirements, proposes an approach for supporting changes of routing strategy in an automated material flow system by utilising the integration. The approach includes (re-)planning of the automated material flow system, commissioning its logic control and controlling the material flow. Floroian et al [4] presents the problem of shop floor agility. One of the critical elements in any shop floor reengineering process is the way the manufacturing control/supervision architecture is changed or modified to accommodate for the new process and equipment. This paper, therefore, proposes a multiagent architecture to support the fast adaptation or changes in the control/supervision architecture. Kopecek[5] deals with a heuristic approach to material supplies of assembly lines (e.g., automotive industry) and for optimization of a stacker which is used in production lines or stores.

Fixture Design

A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labour by simplifying how work pieces are mounted, and increasing conformity across a production run. A fixture differs from a jig in that when a fixture is used, the tool must move relative to the work piece; a jig moves the piece while the tool remains stationary.

Wang et al [6] concetrates on computer aided fixture design, significant works done in the CAFD field, including their approaches, requirements and working principles. Karad et al [7] deals with the design and analysis of the welding fixture for the fuel tank mounting bracket. The deformation on mounting bracket due to clamping and of rotating disc due to loading of all parts have been found using FEA by using ANSYS software.Tong et al [8] describes how to use UGNX and Computer Aided Design Technology to carry out automotive welding line fixture design from the following three aspects which include standardization, modularization and software secondary development. Standardization includes universal parts standardization and private parts standardization; modularization includes parts modularization and fixture unit modularization; software secondary development includes automatically generating two-dimensional map frame, details column of two-dimensional assembly drawing and automatically generating technology requirement of fixture parts. Zhang et al [9] proposes computer aided welding fixture design as methodology. Based on this methodology, the design process is then presented, including: defining requirements, gathering and analyzing the information, fixturing design procedure, fixture design check and verification and post process. Shinde et al [10] proposes new fixture design reduces cycle time and operator labour while increasing functionality; and allows complex welding operations to be completed on simple two axis welding arms.

METHODOLOGY

Initially, various types of Electrical Stackers which are manufactured by Maini Materials Movement is noted. Various Models, Variants, Corresponding Chassis and Carriage part numbers have been noted. The Assembly process sheet is the one which contains the information like the step by step procedure, pictorial representation, information about the parts assembled (part number, description, quantity), exploded view of assembly, torque value information, information about tools used and information about wiring, hydraulic circuit etc. Assembly process sheet were prepared for complete assembly two most selling model namely ST 15 std Tele and ST 15 SS FFTL. Time taken for each process noted and Critical Path Method is applied to determine Cycle time, Critical path and critical activities. The tables 1 & 2 represents

CPM for ST 15 std Tele.

Table 1: Sequence of Assembly Process for ST 15 std Tele

Activity No.	Part No	Description	Qty	Work Hour (Min)
A	80.0015 C2	Chassis Mounting	1	5
B	20.0006	Support wheel unit	2	10
C	20.0007	Support wheel assembly	2	10
D	50.0002	Load Wheel unit	2	10
E	50.0003	Load Wheel assembly	2	10
F	21.0064	Drive unit assembly	1	60
G	10.0013_1	Hydraulic installation Sub Assembly	1	10
H	10.0013	Hydraulic installation	1	50
I		Hydraulic circuit std Tele(Incl Piping)	1	75
J	60.0008	Tiller arm installation	1	60
K	15.0113	Electrical Panel Assembly	1	60
L	50.3993_1	Main Switch Bracket Sub Assembly	1	10
M	71.1050,71.1149	Power Wiring and Control Wiring	1	60
N		Program feeding and Checking	1	15
O	81.0056_1	Stand on Platform sub assembly	1	40
P	81.0053	Stand on Platform assembly	1	10
Q	70.0055	Battery Installation	1	30
R	40.0018	Mast Installation	1	15
S		Mast Installation on Chassis	1	35
T	30.0020	Cylinder Assembly	2	50
U	40.8252_1	Chain Sub Assembly	2	10
V	90.0016	Carriage Installation	1	10
W	90.0016	Carriage Installation on chassis	1	35
X	19.0027	Cover Assembly	1	25
Y		Oil filling, Lift and Load testing	1	60
Total				**765**

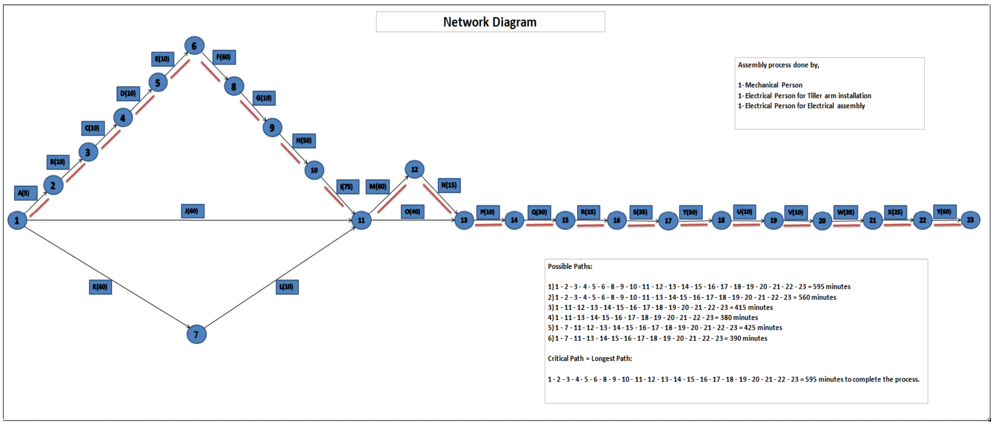

Figure 2: Hydraulic Circuits

Table 2: Critical Path Method Table

Activity	Immediate Predecessor Activity	Normal Time (Min)	On Critical Paths	Earliest Start (ES) (Min)	Earliest Finish (EF) (Min)	Latest Start (LS) (Min)	Latest Finish (LF) (Min)	Slack (ES-LS) (Min)
A	None	5	Yes	0	5	0	5	0
B	A	10	Yes	5	15	5	15	0
C	B	10	Yes	15	25	15	25	0
D	C	10	Yes	25	35	25	35	0

E	D	10	Yes	35	45	35	45	0
F	E	60	Yes	45	105	45	105	0
G	F	10	Yes	105	115	105	115	0
H	G	50	Yes	115	165	115	165	0
I	H	75	Yes	165	240	165	240	0
J	None	60	No	0	60	180	240	180
K	None	60	No	0	60	170	230	170
L	K	10	No	60	70	230	240	170
M	I, J, L	60	Yes	240	300	240	300	0
N	M	15	Yes	300	315	300	315	0
O	I	40	No	240	280	275	315	35
P	N, O	10	Yes	315	325	315	325	0
Q	P	30	Yes	325	355	325	355	0
R	Q	15	Yes	355	370	355	370	0
S	R	35	Yes	370	405	370	405	0
T	S	50	Yes	405	455	405	455	0
U	T	10	Yes	455	465	455	465	0
V	U	10	Yes	465	475	465	475	0
W	V	35	Yes	475	510	475	510	0
X	W	25	Yes	510	535	510	535	0
Y	X	60	Yes	535	595	535	595	0
Assembly Process Completion Time =					**595**			
Number of Critical Path =					**1**			

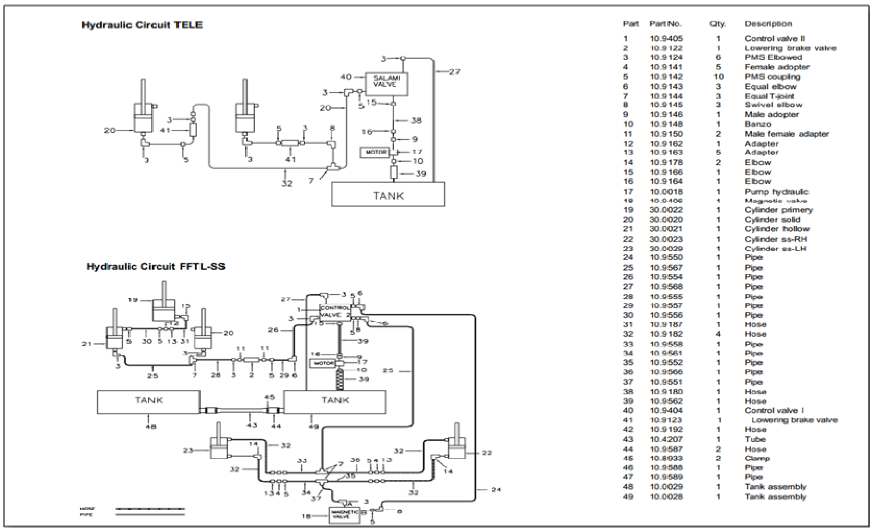

Figure 3

One of the measure taken for assembly process improvement is to standardize the hydraulic pipe end fitting by changing it from BSP to JIC end fitting. In this project, it is carried out for two models namely ST 15 std and ST 15 SS FFTL. Time taken for bending and fitting the hydraulic pipes are 60 and 120 minutes respectively for ST 15 std Tele and ST 15 SS FFTL. Since tools required for that is not available in that plant, the end steel pipe has to be out sourced along with required bending. So dimensions of currently using steel pipes are noted and 3D modeling is done and Design drawings are created using Creo 3.0 software. And drawing is released for the procurement. Figure 3 represents hydraulic circuits. The cost related to present BSP end fitting along with pipes are tabulated and shown in the table 3.

Table 3: Hydraulic Pipe Details

				Related Cost		
Sl No	Description	Part No	Details (In mm) (90 degree bend)	Pipe (132rps/m)	Adapter (50rps/pc)	Total
ST 15 std Tele						
1	Pipe 1	50009689	85, 350	59	100	159
2	Pipe 3	50009691	90, 180	114	100	214
3	Pipe 4	50009692	100, 160	121	100	221
4	Pipe 5	50009693	220, 280, 180, 340	135	100	235
5	Pipe 6	50009694	520, 280, 180, 340	174	100	274
Total						1103
ST 15 SS FFTL						
1	Pipe 1	50009689	85, 350	59	100	159
2	Pipe 4	50009692	150, 90	32	100	132
3	Pipe 7	50009695	100, 160	34	100	134
4	Pipe 9	50009697	200, 90	38	100	138
5	Pipe 10	50009698	120, 670, 110, 250, 280	189	100	289
6	Pipe 11	50009699	120, 675, 140, 110, 280	175	100	275
7	Pipe 12	50009852	220, 280, 180, 450	149	100	249
Total						1788

By studying the Assembly process sheet, various sub-assemblies are suggested to directly import from outside so that the cycle time will be reduced. Load wheel sub assembly, support wheel sub assembly, Stand on platform sub assembly, cross head sub assembly, hydraulic tank sub assembly, side stabilizer sub assembly are suggested. And, necessary modeling and design drawings are done using Creo 3.0 software and released for the procurement. Sub assembly details are shown on Table 4.

Table 4: Sub Assembly Details

Sl. No	Part No	Description	Sub parts	Qty/MC	Price (Rs)	Time Taken (Min)
1	50008260	Support wheel unit	11	2	1933.6	10
2	50006953	Stand on platform assy & inst	16	1	3483.75	40
3	50008309	load wheel assembly	7	2	1389.6	10
4	50009806	SS arm sub assembly LH	5	1	819.5	10
5	50009924	SS arm sub assembly RH	5	1	840.44	10
6	50009807	Cross head sub assembly	5	1	2094	10
7	50007033	Tank weldment	6	1	1692	20

Since Stackers chassis welding should be done in plant, proper fixtures have to be used. At first, proper Bill of Material should be prepared for the procurement of base parts of chassis. And any change in the part drawing has to be suggested in order to make final product quality one. And economic fixtures has to be designed and manufactured so that resulting cost does not exceed the previous outsourcing method. Fixture fabrication started inside the plant along with weldment of 1st sample of ST 15 Tele. Raw materials like C section channels, solid and circular bar were ordered. Horizontal and vertical clamps are selected according to clamping force required. Various locating pins and supporting rods are modeled and procured. Finally, 1st sample of chassis and fixture manufacturing is finished. 1st chassis sample is inspected and any variation in that is noted and properly incorporated in the fixture. Then production of chassis weldment started using the fixture and welding process sheet is developed. Figure 4 contains the photos of fixture developed.

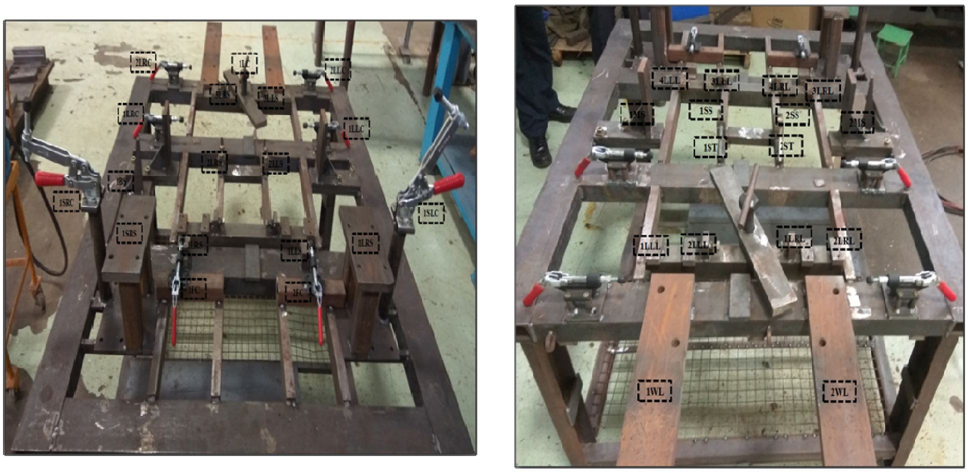

Figure 4: Main Fixture.

Currently across, the Stacker models of various type of drive units are used. Namely 1 kW AC Horizontal, 1.5 kW AC Vertical, 1.5 kW DC Vertical and 2.6 kW DC Vertical. And also, it was imported from Italy. Then, it is decided to rationalize the 1.5 kW AC vertical across all the model and also to localize buying vendor. Drive motor inspection report comparing between C.F.R and Prime movers are shown in table 5. It will result in reduction of price, Minimum order quantity and also reduction in inventory turnover. Design of all the stackers and Drive unit from Localized Vendor are studied.

One of the main use of Stackers was to lift the particular load and transport or to place it on racks at particular height. So forks or carriage are used for this purpose. And these carriages are lifted with the help of Mast and hydraulic cylinder of proper height. For one model, there are different variant depending upon the mast and cylinder height. So, it is decided to rationalize the mast and cylinder height in order to decrease the number of variant. So, they are grouped in such a way that one standard height will be provided with limit switches. If any customer wants lesser height, than that it will be indicated with the help of limit switches. Advantages are Shorter lead times of Hydraulic Cylinders and Mast assemblies, Faster deliveries to Customers, Variants reduced from 30 to 11 on equipment build, Better volumes to vendors, scope for price reduction, Better inventory control.

Table 5: Drive Motor Inspection Report

Drive Motor Inspection Report- Stackers				
Sl No.	**Description**	**Prime Motor Specification**	**Cfr Motor Specification**	**Remark**
1	Model	ST 15i W TELE	ST 15i W TELE	
2	Capacity	1400 Kg	1400 Kg	
3	Floor Condition	Flat Surface	Flat Surface	
4	Drive Motor Make	PRIME MOVER ENGG. CO. (P) LTD.	CFR Modena-Italy	
5	Drive Motor Spec	1.5 kW, 4186 RPM, Insulation F type, 140Hz, S2 60min Rating	1.5kW, 2900 RPM, Insulation F type, 100Hz, S2 60min Rating	
6	Drive Motor Serial No.	150851022	00 000288	

7	Controller Spec		1232	1232	
8	Ambient Noise Level		55 db	62 db	
9	Applicable Models		ST 15i SERIES, SP 25i Models	ST 15i SERIES, SP 25i Model	
Drive Motor Testing Parameters					
Sl No.	**Testing Parameters**	**Specification**	**Prime Motor**	**Cfr Motor**	**Remarks**
1	Gradeability- Laden	8% MAX	Not Checked	Not Checked	
2	Gradeability- Un Laden	10% MAX	Not Checked	Not Checked	
3	Travelling Speed- Laden	5.5 Km/hr (+/- 10%)	6.4 Km/hr	6.2 Km/hr	Travelling Speed can be adjustable
4	Travelling Speed- Un Laden	6.5 Km/hr (+/- 10%)	7.5 Km/hr	7.4 Km/hr	
5	Controller Current- Laden	No Specification	62 Amps	80 Amps	Current drawn is less in Prime Motor compared to the CFR Motor
6	Controller Current- Un Laden	No Specification	42 Amps	48 Amps	
7	Controller Current- Lifted Condition	No Specification	22 Amps	33 Amps	
8	Motor Noise- Laden	No Specification	93 db	80 db	Noise Level is more in Prime Motor compared to CFR Motor. Motor Noise is getting increased as observed after continuous running. Initially, Noise was 88db later after run for 10min Continuously observed is 93 db
9	Motor Noise- Un Laden	No Specification	88 db	87 db	
10	Motor Noise- Lifted Condition	No Specification	80 db	85 db	
11	Motor Sensor Type	No Specification	Internal Mounting Bearing Sensor type	External Mounting Speed Sensor	Currently, CFR used is External mounting Speed Sensor type. Internal Mounting Bearing Sensor having Customer Complaint
12	Brake Gap Settings	No Specification	No Factory Setting done	Factory Setting	CFR Currently Brake Setting will be Factory Set, but in the Prime Movers Motor, as discussed, it is with Service Brake set In House
13	Brake Pad Spline holding with Motor Gear	Splines should hold 100% with Gear	20% Holding	100% Holding	Brake pad Splines holding only 20% in Drive Motor gear

14	Brake Pad Sound when Brake Applied suddenly	No Specification	More Sound	Less Sound	Brake pad sound is high when Brake is applied suddenly in Prime Motor compared with the CFR Motor

RESULTS AND DISCUSSIONS

In the present study, two most selling models are considered i.e., ST 15 Std Tele and ST 15 SS FFTL. Each model contains wheel assembly process, Hydraulic, Electric, Battery, Mast and Carriage Installation and finally packing along with inspection. In order to reduce the cycle time for assembly process, many steps are taken. By studying the assembly process sheet, critical activities are noted. And the methods like Sub assembly concept and changing end pipe connection are introduced . Both resulted in decrease in cycle time which is shown in tables 6 and 7. It can be seen that there is a decrease of 15.12% in the cycle time for ST 15 Std Tele and 19.65% in ST 15 SS FFTL.

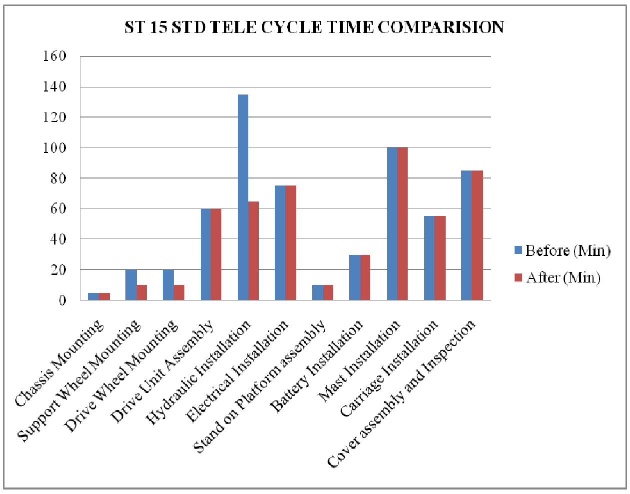

Figure 5

Table 6: ST 15 Std Tele Cycle Time Comparison

Activity No	Description	Before (Min)	After (Min)
1	Chassis Mounting	5	5
2	Support Wheel Mounting	20	10
3	Drive Wheel Mounting	20	10
4	Drive Unit Assembly	60	60
5	Hydraulic Installation	135	65
6	Electrical Installation	75	75
7	Stand on Platform assembly	10	10
8	Battery Installation	30	30
9	Mast Installation	100	100
10	Carriage Installation	55	55
11	Cover assembly	85	85
Total Cycle time on critical path		**595**	**505**

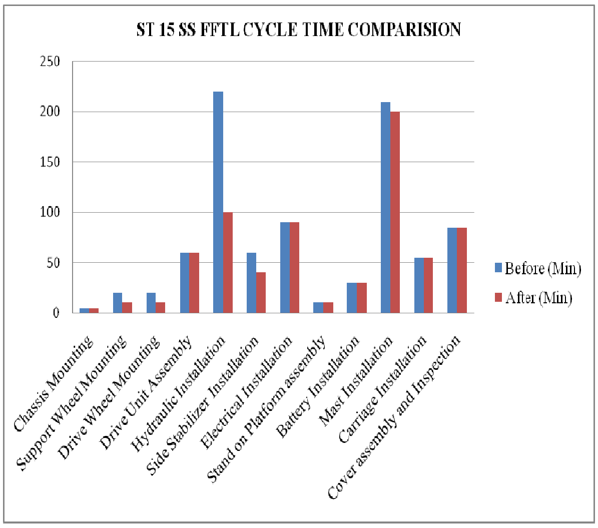

Figure 6

Table 7: ST 15 SS FFTL Cycle Time Comparison

Activity No	Description	Before (Min)	After (Min)
1	Chassis Mounting	5	5
2	Support Wheel Mounting	20	10
3	Drive Wheel Mounting	20	10
4	Drive Unit Assembly	60	60
5	Hydraulic Installation	220	100
6	Side Stabilizer Installation	60	40
7	Electrical Installation	90	90
8	Stand on Platform assembly	10	10
9	Battery Installation	30	30
10	Mast Installation	210	200
11	Carriage Installation	55	55
12	Cover assembly	85	85
Total Cycle time on critical path		**865**	**695**

Initially, Stacker Chassis weldment is done outside. As the demand increases, it is also required to fabricate chassis inside the plant as quick as possible. So, it is decided to use Fixture for the Welding process. Initially, it is planned to buy fixture from outside. As, it is priced around 14 lacks, it was decided to fabricate Fixture also inside the plant. Fixture is fabricated along with 1st sample of ST 15 Std Tele Chassis and the price were around only 50 thousand. Then, Welding process sheet is done for the process and cycle time is noted. It is compared with cycle time of welding process without fixture. It is shown in table 8. It is seen that there is a reduction of around 26.16% in cycle time with the help of fixture.

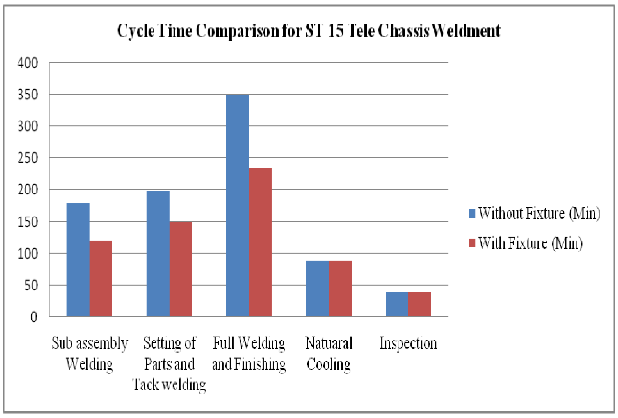

Figure 7

Table 8: Cycle Time Comparison for ST 15 Tele Chassis Weldment

Activity No	Description	Without Fixture (Min)	With Fixture (Min)
1	Sub assembly Welding	180	120
2	Setting of Parts and Tack welding	200	150
3	Full Welding and Finishing	350	235
4	Natural Cooling	90	90
5	Inspection	40	40
Total Cycle Time		**860**	**635**

Under this, it is decided to rationalize the 1.5 kW AC vertical drive across all the stacker models. Also, it is decided to decrease the number of variant depending upon the mast height. As a result of these standardization, there is reduction in price of around 25,366 Rs for ST15 Std Tele and 25,458 Rs for ST 15 SS FFTL. These are shown in tables 9 & 10.

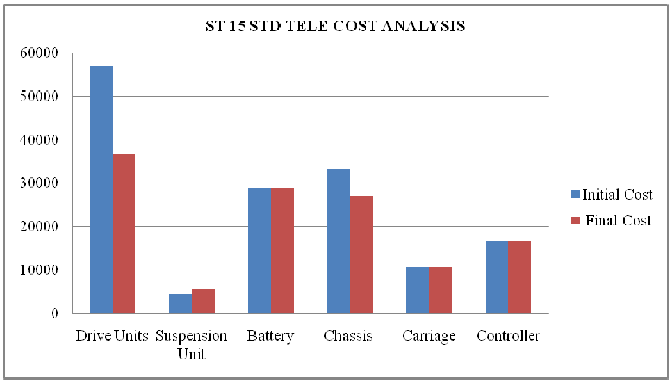

Figure 8

Table 9: ST 15 Std Tele Cost Analysis

Activity No	Description	Initial Cost	Final Cost
1	Drive Units	56918	36750
2	Suspension Unit	4474	5485
3	Battery	28875	28875
4	Chassis	33201	27022
5	Carriage	10745	10745
6	Controller	16422	16422
Total		**150635**	**125299**

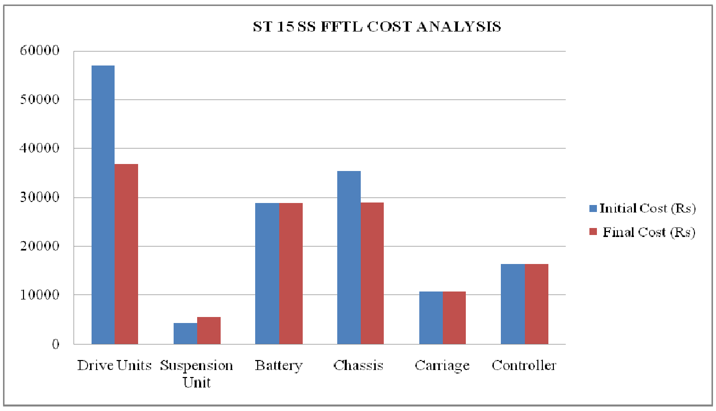

Figure 9

Table 10: ST 15 SS FFTL Cost Analysis

Activity No.	Description	Initial Cost	Final Cost
1	Drive Units	56918	36750
2	Suspension Unit	4474	5485
3	Battery	28875	28875
4	Chassis	35301	29000
5	Carriage	10745	10745
6	Controller	16422	16422
Total		**152735**	**127277**

CONCLUSIONS

Maini Materials Movement private Limited provides various solutions for material handling like Pallet Trucks, Stackers, Tow Trucks, Reach Trucks etc. As there is an increase in demand and in order to meet the demand of customer, it is required to take measures which will result in reduction of cycle time and correspondingly increase in the production. And also, it is necessary to find a way with which there will be reduction in the cost of manufacturing.. One of the methods is by standardization. Various methods are implemented and proposed to achieve the objective of the study. Following conclusions are drawn from these methods:

By introducing Sub assembly concept and Hydraulic end pipe kits, it can be seen that there is a decrease of 15.12% in the cycle time for ST 15 Std Tele and 19.65% in ST 15 SS FFTL. Other advantages of these are

- Inventory bins reduced from X to 1
- There will be decrease in Administrative cost like cost related to Purchase order, Cost of Maintaining inventory and Cost of Assembly

It is seen that there is a reduction of around 26.16% in cycle time for ST 15 Std Tele Chassis Weldment with the help of fixture. The total cost of fabricated fixture is about 50 thousand against 14 lacks proposed by outside vendor. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run.

As a result of Standardization of stackers, there is reduction in price of around 25,366 Rs for ST15 Std Tele and 25,458 Rs for ST 15 SS FFTL. Advantages of Rationalizing 1.5 kW AC Vertical Drive are,

- 4 different models of Drives reduced to 1
- The procurement of Drive Unit localized
- Reduced Inventory turnover and Material Ordering Quantity

Advantages of Standardizing Lifting heights are,

- Shorter lead times of Hydraulic Cylinders and Mast assemblies
- o Faster deliveries to Customers
- Variants reduced from 30 to 11 on equipment build
- Better volumes to vendors
- Scope for price reduction and Better inventory control

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